DEPARTMENT OF THE ARMY CORPS OF ENGINEERS

BEACH EROSION BOARD

OFFICE OF THE CHIEF OF ENGINEERS

CHANGES IN SAND LEVEL ON THE BEACH AND SHELF AT LA JOLLA, CALIFORNIA

TECHNICAL MEMORANDUM NO. 82

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ERRATA SHEET

TECHNICAL MEMORANDUM NO. 82

"Changes in Sand Level on the Beach and Shelf at La Jolla, California"

Page 1 - under title, name of co-author should read G. A. Rusnak.

" - in 1st line under Introduction, change "qualitative" to "quantitative".

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JULY 1956

FOREWORD

Accurate determination of sand level changes over the nearshore area is important in making engineering analysis of littoral movement -- for both civil and military purposes. Derivation of the relation between these changes and the causative wave, water level, and tide forces would permit prediction of future change. Extremely accurate measurement of this change has been made for a three-year period by periodic diver observation of the sand level against a series of stationary reference rods driven into the sand bottom. This report presents the results of these observations. The report also shows comparison with results obtained by electronic sounding methods, demonstrating that unless great care is taken, large daily differences may be erroneously observed in acoustic measurements.

This report was prepared at the Scripps Institution of Oceanography of the University of California in pursuance of contracts with the Beach Erosion Board and the Office of Naval Research. The authors of the report, D. L. Inman, and G. A. Rusnak, are members of the staff of that institution.

Views and conclusions stated in this report are not necessarily those of the Beach Erosion Board.

This report is published under authority of Public Law 166, 79th Congress, approved July 31, 1945.

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CHANGES IN SAND LEVEL ON THE BEACH AND SHELF AT LA JOLLA, CALIFORNIA*

by

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ABSTRACT

Changes in the level of the sandy bottom were measured periodically over an interval of almost three years at stations extending from near the surf zone to a depth of 70 feet. A reference level was established at each station by forcing six rods, spaced at intervals of 10 feet, into the bottom and changes in sand level were based on the average of the differences in length of rod exposed from survey to survey. Measurements, which were performed by swimmers equipped with self-contained underwater breathing apparatus, resulted in a standard error of about ±0.05 foot per survey in the determination of net sand level.

The total range in sand level probably exceeds 2 feet at the 18-foot deep station, where changes in excess of 0.6 foot were measured before the reference rods were lost. The magnitude of change decreases with increasing depth; changes of 0.29, 0.16, and 0.15 foot were measured at stations where the depth of water was 30, 52, and 70 feet respectively. Estimates of sand level variation, made for monthly and seasonal periods, indicate that significant changes occur between monthly periods at the 30 and 70-foot depths, and that significant seasonal changes occur at the 30 and 52-foot depths. At the deepest station overall seasonal variations are relatively small in comparison with changes of shorter period.

Comparison of acoustic soundings with reference rod measurements indicated that the accuracy of the acoustic sounding method was of the order of $\pm \frac{1}{2}$ foot for these operating conditions.

INTRODUCTION

The qualitative evaluation of the deposition and erosion of sediments near shore is usually based on differences obtained by comparing successive topographic surveys. In general the surveys are quite accurate for those portions of beach which are above water level, where standard leveling and positioning techniques can be employed.

*Contribution from the Scripps Institution of Oceanography, New Series No. 854.

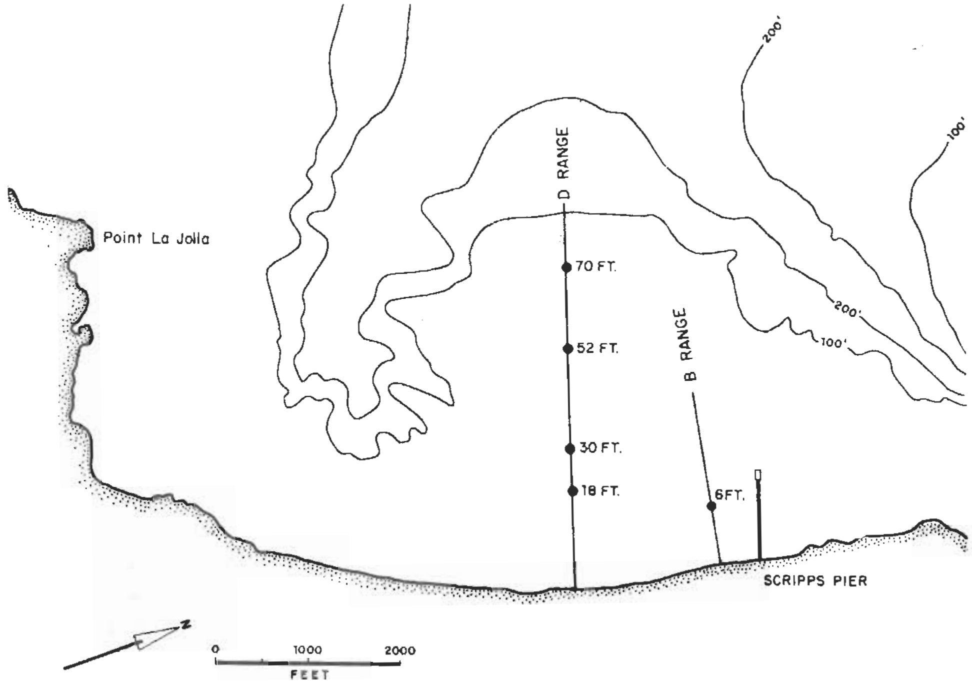
Below water level the depth to the bottom is usually measured acoustically or with sounding lead and the bottom elevation estimated by correcting that depth for tides, waves, and various other effects. This method of hydrographic survey is relatively inaccurate as compared to the precise leveling techniques which are carried out above water.

Seasonal and long term changes in the level of nearshore sediments commonly are greatest along the narrow section of beach foreshore which falls within the intertidal zone. The magnitude of change in level decreases seaward, probably reaching a minimum on the broad flat shelves extending away from the beaches. Since the shelf areas are large in comparison with the narrow strip of beach bordering them, relatively small errors in determining sand level on the shelf may result in very large errors in estimating the total sand budget.

Attempts to evaluate the accuracy of hydrographic surveys have been made on several occasions, but the reliability of such investigations has been subject to uncertainty because of the lack of an accurate level upon which to base the surveys. The advent of self-contained breathing apparatus (SCUBA), which allows swimmers to move about freely and to make measurements and observations underwater, has provided a means of establishing underwater levels and accurately measuring changes from this level. A level is established by forcing a long rod a sufficient distance into the sandy bottom and in such a manner as to assure its remaining in a stationary position so that it does not move when material is deposited or eroded from the area. Thus, ideally, a direct comparison of the level of the exposed portion of the reference rod on two successive surveys will give the net value of erosion or deposition between surveys. A series of four stations using reference rods of this type was established on the sandy shelf off La Jolla in order to determine accurately the magnitude of erosion and deposition and to evaluate the accuracy of hydrographic surveys which use acoustical methods. Three of these stations were sampled periodically during an interval of almost three years. In addition to these stations, a series of reference rods was placed along a beach profile extending through the surf zone in order to measure small changes in sand level which occur during short intervals of time such as half-tidal cycles.

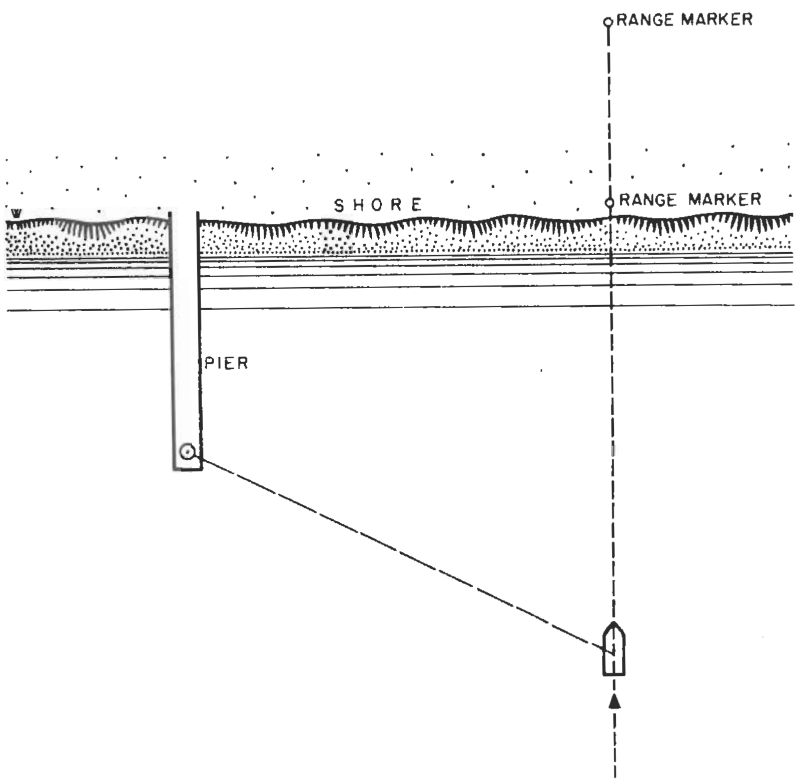
METHOD

A series of four stations were established on a range running normal to the coast line and extending from near the breaker zone out to the level portions of the sandy shelf (figure 1). Locations were selected where the depth of water was approximately 20, 30, 50, and 70 feet to allow a progressive comparison in changes of sand level from the surf zone, where fluctuations in level were known to be large, out to greater depths on the shelf. In the final analysis the exact location of the stations was determined by the proximity of good visual ranges and cross-ranges, since ease of positioning is an important factor in the economy of field operations.



Index chart showing the location of ranges and stations. Six reference rods were placed at each station on D range. Single rods were placed at 20-ft. intervals along a profile through the surf zone on B range. Depths are in feet below mean lower low water.

FIGURE I · INDEX CHART



The four stations on D range were located by running shoreward along a visual range to positions determined by the angle between the range and the pier. The angle was measured by sextant from the boat.

FIGURE 2 · METHOD OF POSITIONING

It was the intention in the experimental design of the field work to increase reliability of observation by making the number of independent measurements at any one station and time as large as practical, and by sampling each station frequently. Initially six reference rods were placed at each station, and on the average they were measured from one to two times per month. Because the changes in sand level, especially in deeper water, were small, the data were subjected to various statistical analyses in order to evaluate the contributing factors. The procedures used in processing the data are described in a separate section.

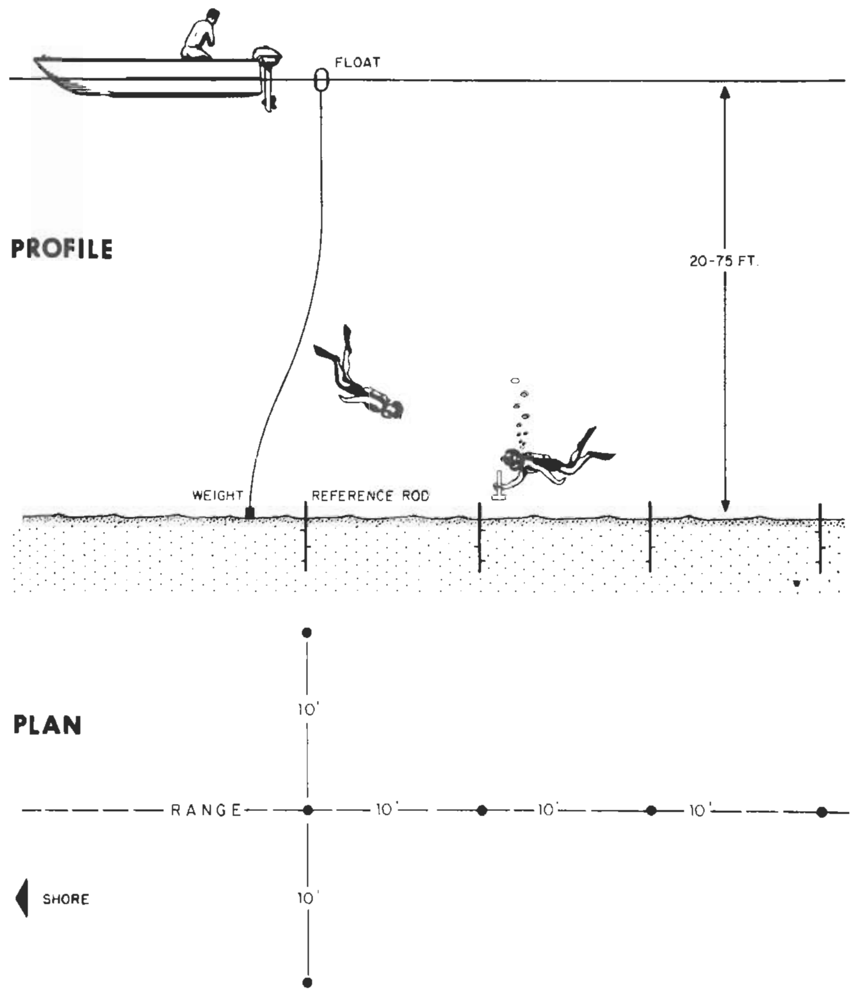
POSITIONING

During surveys the station locations were determined by range and horizontal sextant angle. A range was obtained by aligning visually two range markers on shore and the small craft proceeded shoreward along this range until the appropriate angle was obtained between the range and the end of the Scripps pier, at which point a marker was dropped in the water (figure 2). The marker consisted of a small cylindrical float with line wrapped around it and a ten-pound lead attached to the free end of the line. The lead sounded rapidly, causing the cylinder to spin in the water as the line unwound. Swimmers equipped with SCUBA were then guided to the location of the station by following the line to the bottom (figure 3).

This method of positioning proved to be accurate and quick and provided the swimmers with a visual reference upon which to orientate themselves. As a measure of accuracy, the rest position of the sounding lead relative to the six reference rods is shown for the 45 observations made at the 30-foot deep station (figure 4). The position of the sounding lead reflects the effects of waves and currents as well as the error in positioning at the time the marker float was placed in the water. Even so, the sounding lead landed within a radius of 5 feet of the target (reference rod number 1) about 50% of the time and within a radius of 10 feet about 80% of the time. The radius of error was slightly greater at 52-foot and 70-foot depths.

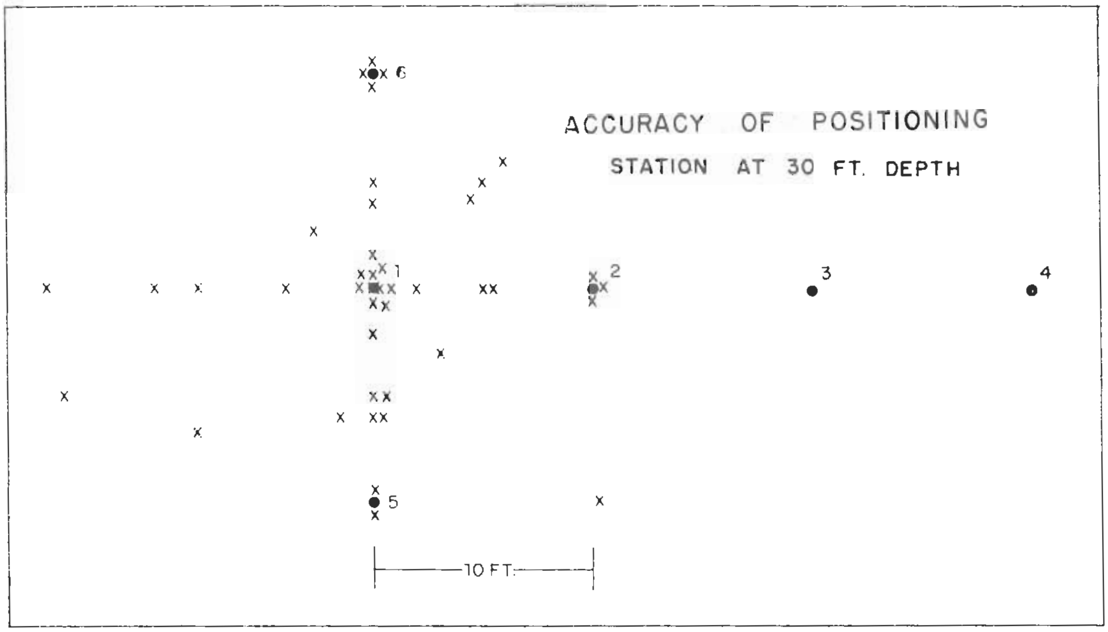
REFERENCE RODS

The basic problem was to find a means of establishing a stationary reference level near the bottom from which fluctuations of the sandy bottom could be measured. The solution used here was to force rods into the bottom in such a manner as to assure their remaining stationary when material is eroded or deposited in the area. For this purpose, brass rods 3/8 inch in diameter and 4 feet long were pounded approximately 3 feet into the bottom with a light sledge hammer. Circular brass rings were silver-soldered around the lower portion of the rods so that once emplaced in the sand they could not easily be raised or lowered. Deformed steel reinforcing rods were also tested, but their



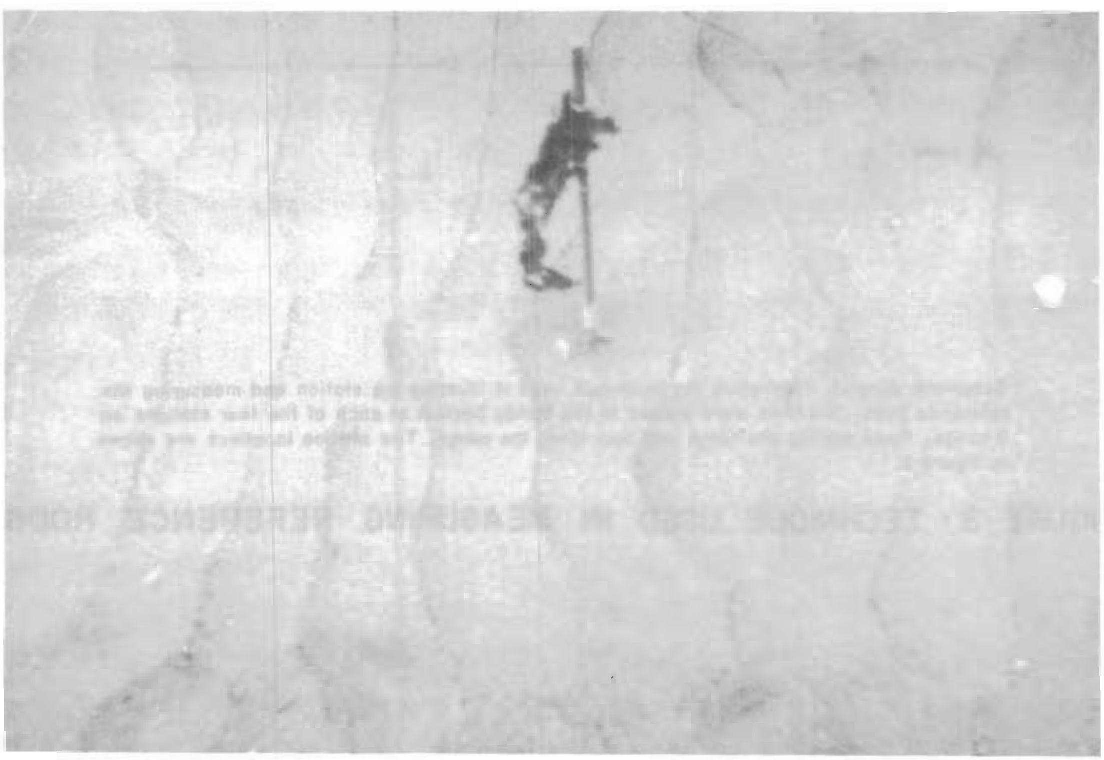
Schematic diagram illustrating the technique used in locating the station and measuring the reference rods. Six rods were placed in the sandy bottom at each of the four stations on D range; three across the range and four along the range. The station locations are shown in figure 1.

FIGURE 3 · TECHNIQUE USED IN MEASURING REFERENCE RODS



Accuracy of positioning indicated by the rest position of the sounding lead for each of the 45 observations at the 30-foot depth. The position of the sounding lead, shown by X, reflects the effect of waves and currents as well as the error in positioning the boat.

FIGURE 4 · ACCURACY OF POSITIONING



Underwater photograph of one of six reference rods at the station in 30 feet of water. The rod is 3/8-inch diameter brass; approximately 1 foot is exposed, and 3 feet are buried in the sand. The dark object is a plastic tag with growing hydroid. Note the slight scour depression at the base of the rod.

FIGURE 5 · UNDERWATER PHOTOGRAPH OF REFERENCE ROD use was discontinued because it was found that hydroids and other organisms grew profusely on the steel, whereas the brass was found to be relatively free from fouling organisms. Fouling on the steel rods made measurement more difficult and increased the stress exerted on the rod by the moving water and the degree of scour at the base of the rod. In general, only a very slight scour depression formed in the sand at the base of the brass rods, as shown in figure 5.

Six rods were forced into the bottom at each of the four stations on D range. They were placed 10 feet apart in a "T" formation, with four rods along the range and three across (figure 3). The distance between rods was sufficient to eliminate the possibility of significant hydraulic interference or influence between rods.

After the rods had been in place several days and were in equilibrium with their environment, the station was again visited and the length of each rod carefully measured. This length was recorded as the reference length for that rod and is the length upon which future changes in sand level were based. For each successive survey the new length of rod was subtracted from the reference length, and the mean value of the differences for the six rods used as a measure of the new sand level. The differences from reference length for each rod during each survey, together with the mean difference and standard deviation, are listed in Appendix IA-ID. The mean difference is graphed as a function of time in figure 7. The particle size distribution analyses of the sand samples collected by the swimmers at each station are listed in Appendix IIIA-IIID.

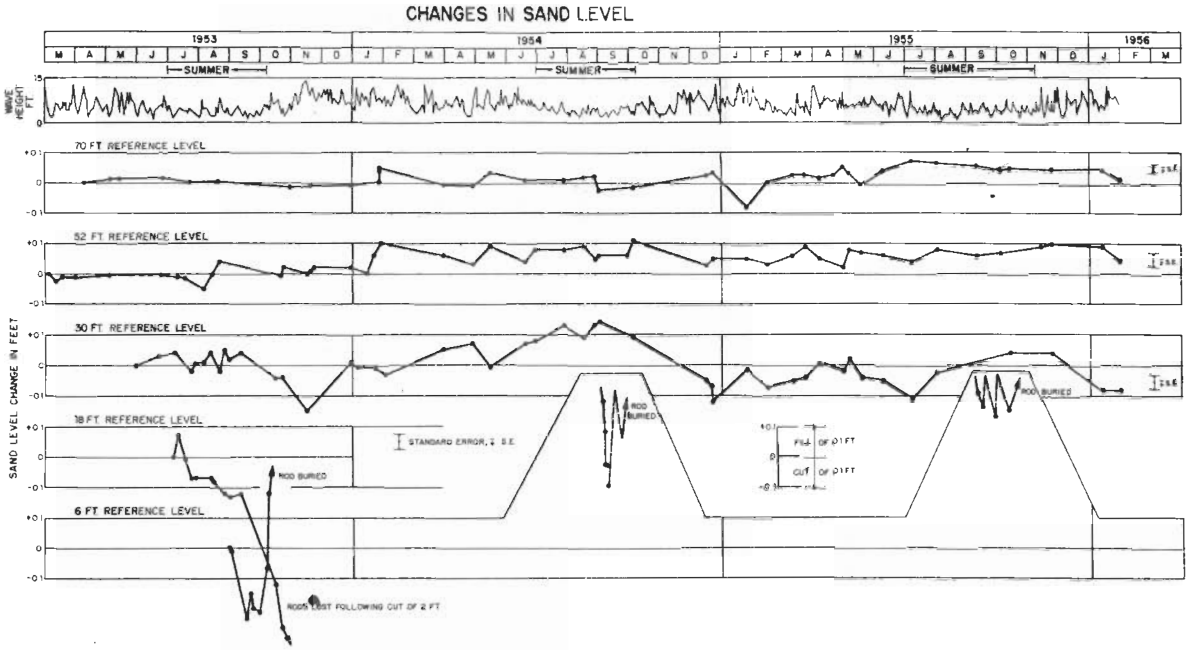
The length of rod was measured by placing a plexiglas device upright on the sand alongside the rod and marking the device with a grease pencil. The measuring device, which consisted of a 2-foot long strip of plexiglas with an 8-inch wide by 1-inch thick strip of wood at its base, resembled a draftsman's "T" square (figure 6). The base was wide and thick so as to bridge or cover holes that might be present at the base of the rod and to avoid settling into the sand when placed beside the rod.

The lengths of each of the six rods at each station were marked on the device. When the swimmer returned to the surface, these lengths were measured to the nearest hundredth of a foot and recorded for processing as described above.

During the summer of 1953 a series of reference rods were placed at 20-foot intervals along a profile through the surf zone on B range (figure 1). The line extended from the upper portion of the beach foreshore out to a depth of approximately 6 feet below MLLW (figure 8). The section of beach above water level was surveyed by transit, and the portion under water by swimmers and reference rods in the manner outlined for the stations on D range, excepting that only one

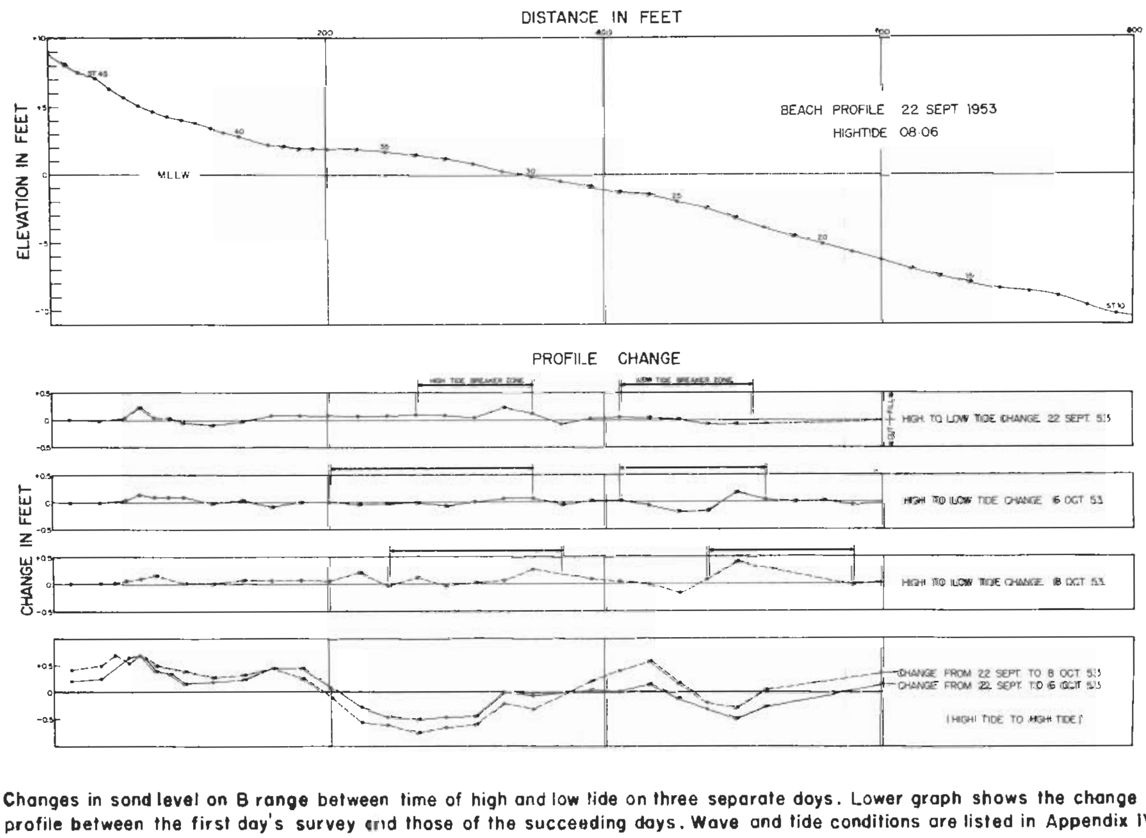
Swimmer equipped with self-contained breathing apparatus (SCUBA), exposure suit, and plexiglas device used in obtaining the length of reference rods. The length is marked on the plexiglas with grease pencil (attached to device by clip) and measured after returning to the surface.

FIGURE 6 · SWIMMER EQUIPPED WITH SCUBA AND MEASURING DEVICE



Changes in sand level with time. The stations at depths of 18, 30, 52, and 70 feet are on D range and the fluctuations in sand level are based on the mean of six reference rods at each station. The magnitude of two values of the standard error, ± S.E., is shown as a measure of reliability of the observations. The station at a depth of 6 feet was on B range and consisted of a single reference rod which was completely covered with sand during the winter. The wave heights are for significant breakers at the point of wave convergence near D range.

FIGURE 7 · CHANGES IN SAND LEVEL WITH TIME



Changes in sand level on B range between time of high and low tide on three separate days. Lower graph shows the change in profile between the first day's survey and those of the succeeding days. Wave and tide conditions are listed in Appendix IV.

FIGURE 8 · CHANGES IN BEACH PROFILES DURING TIDAL CYCLES

reference rod was used per station. Positioning was performed by the swimmer in the water using a visual range and a series of cross ranges. The pilings of the Scripps pier provided convenient, evenly spaced markers, which when aligned with a distant marker, made accurate visual cross ranges.

The profile of closely spaced rods through the surf zone was established in order to measure small changes in sand level which occur during half-tidal cycles. Complete surveys were made at the time of high tide and at the following low tide on three days. The changes in sand level are graphed in figure 8, and the tide and wave conditions are listed in Appendix IV.

ACOUSTIC SOUNDING

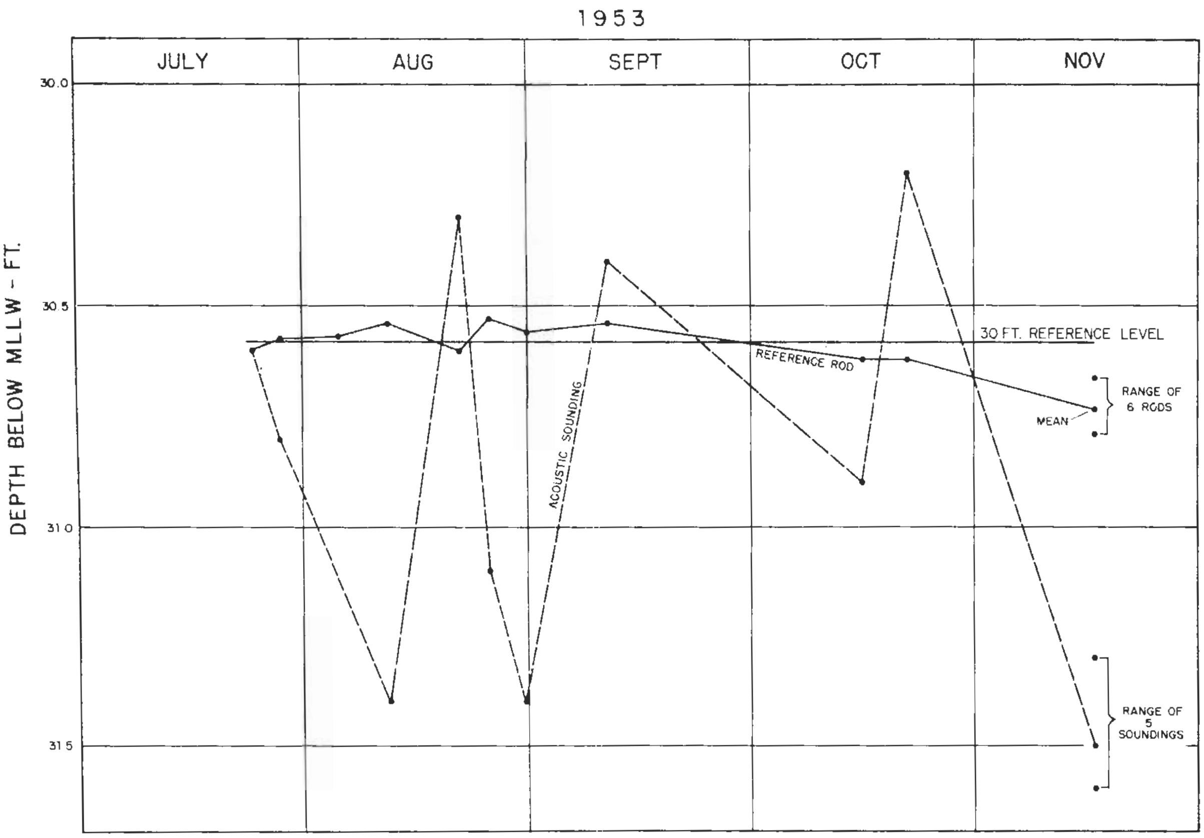
During the summer and fall of 1953 hydrographic surveys were made along D range concurrently with the reference rod measurements in order to evaluate the accuracy of the acoustic sounding method. The hydrographic surveys were made from an amphibious vehicle (DUKW) equipped with a Bludworth NK - 2 fathometer and a sounding element rigidly mounted to the side of the DUKW approximately a foot and a half below water level. This fathometer is equipped with gain, frequency, and power controls, marker bar, and has a record scale of 6½ inches equal to 60 feet in depth. The fathometer was calibrated with a lead line which was graduated in tenths of a foot and held vertically in the water beside the sounding element. Approximately six checks were made at each of two depths while the DUKW was in still water. Calibrations were made in water depths of approximately 15 and 30 feet in areas where the bottom was flat and sandy (Shepard and Inman, 1951).

Positioning was performed by visual range and horizontal sextant angles as described previously, and the fathogram was marked at the time of passage over each station. Approximately five sounding runs were made along the range just prior to measuring the reference rods at each station.

The data from the fathogram were corrected for depth and reduced to the datum of MLLW by reference to a tide record from the U. S. Coast and Geodetic Survey tide gauge on the end of Scripps pier (figure 1). A comparison between the acoustic survey and the reference rod measurements for the station at the 30-foot depth is shown in figure 9.

STATISTICAL TREATMENT OF DATA

The primary consideration of any experimental study is generally that of separating the several factors involved in the experiment. In the present study it was important to separate the variability of sand level changes into the several contributing groups of factors under study. To do this, a large group of measures of sand level were collected



Comparison between sand levels obtained by acoustic sounding and reference rods at the 30-foot deep station on D range. Each point represents the mean of approximately 5 acoustic sounding runs or 6 reference rod measurements. Within a single day the range of acoustic soundings is only 3 to 5 times greater than the range in rod measurements. However, between days the acoustic soundings give fluctuations which would result in large errors.

FIGURE 9 · COMPARISON OF ACOUSTIC SOUNDING AND REFERENCE RODS

at specific points in space and time. Then a choice of statistical procedures was made such that the information obtained could be utilized in the most efficient manner.

The natural limitations in this study, such as adverse weather conditions, did not permit the experimental design to be carried out to its best advantage. It is known, for example, that the data are somewhat biased because the measures could not be collected in a completely random manner. Nonetheless, although errors may result because the assumptions underlying the statistical theory have not been completely fulfilled, the statistical theory will not be rejected but will be applied with the condition that caution be used in its interpretation (Fisher, 1949, p. 16). If these limitations are kept in mind, the statistical applications are somewhat justified in that they may lead to the recognition of the causes of departures. As has been pointed out by Olson and Potter (1954), one must use judgment in passing over preliminary stages of analysis more rapidly than statistical rigor would permit in order to focus attention on later critical problems requiring statistical analysis.

With this point of view, several questions were asked in the study of sand level changes. These were: (1) what is the accuracy with which the sand level, at a given depth and at a given time, could be measured; (2) what are the monthly and seasonal variations of sand level; (3) is there a trend in the changes of sand level with time; and, finally; (4) is there a relation between the sand level changes at various depths? The choice of statistical tests used for obtaining estimated answers to these questions was the analysis of variance, the sign test of trend, and the estimate of correlation.

ANALYSIS OF VARIANCE

In a normally distributed population the form of the distribution is completely described by the mean μ and the variance σ^2. A random sample of n items from this population gives an estimate of these parameters in the form of the sample mean $\bar{x}$ and the sample variance s^2 (Dixon and Massey, 1951, pp. 32-35).

$$\bar{x} = \frac{\Sigma x}{n} \tag{1}$$

$$s^2 = \frac{\Sigma x^2 - (\Sigma x)^2/n}{n-1} \tag{2}$$

The fundamental principle upon which the analysis of variance is based is that the variance of the independent factors contributing to the population variance are additive. Therefore, the total population variance is the sum of the independent factors contributing to this variance. In the present study it was desired to separate the independent factors of sand level variability due to local irregularities in sand level (plus measurement error) from those due to variations with time. By grouping the data in a hierarchical scheme, it was possible to separate and evaluate the magnitude of these variations.[1]

The assumptions underlying the analysis of variance are that the observations are from a normally distributed population and that the variance of each group is the same. Dixon and Massey (1951, p. 126) point out, however, that the results of the analysis are changed very little by moderate violations of the assumptions of normal distribution and equal variance.

Example of Analysis of Variance for the Station at 70-Foot Depth. For cases in which the random deviations are normally distributed, the computation of variance is conveniently made by utilizing the conventional form of the analysis of variance table (Eisenhart, *et al.*, 1947, p. 311). The sources of variation are broken down into those (1) between k rods, (2) within j months, (3) between i months, and (4) between h seasons. Arranging the data so that these sources of variation could be separated results in the hierarchical order presented in table 1.

Computational procedure for the first step in the analysis of variance is indicated by the column headings and the summations following table I, part A. The summations are made with a calculating machine and entered directly in this part of the table. The sum totals of these columns are then entered in the analysis of variance table, part B, as lower level sum and higher level sum from the respective columns. The difference of these sums for each source is the sum of the squared deviations and corresponds to the numerator of equation (2). The sum of these squared deviations is then divided by the degrees of freedom to obtain the mean square or variance.

The number of degrees of freedom between rods is the number of rods per observation minus one (k-1), summed over all observations, and is equal to 199 for this station. Within months the number of degrees of freedom is the number of observations per month minus one (j-1), summed over all months and is equal to 11. This same procedure is followed for each successively higher level of sampling (Snedecor, 1946, p. 233).

The mean square between rods is assumed to be due to random sampling fluctuations around the true mean of the group with a true variance σ_k^2. The mean square within months, however, is dependent both upon the between rods variance, σ_k^2, affecting the individual measurements involved in the mean, and on the additional variance component, σ_j^2, due to the fluctuation of sample means around the group mean $\bar{X}_j$. The long-run expected value of the mean square within months is equal to

[1] The reader is referred to standard statistical texts such as Dixon and Massey (1951, Chaps. 8 and 10), Snedecor (1946, Chaps. 10 and 11) or the lucid digest of Olson and Potter (1954) for the complete details of this method of analysis.

Table 1. Analysis of variance for unequal samples of sand level change; station at 70 ft depth.

Part A. Data and computations.

Between Seasons (h)	Between Months (i)	Within Months (j)	Between Rods (k) 1	2	3	4	5	6	$\sum_k x$	$\sum_k x^2$	$\sum_j\left[\frac{(\sum_k x)^2}{N_k}\right]$	$\sum_i\left[\frac{(\sum_{jk} x)^2}{N_j}\right]$
1	1	4 May '53	+.01	-.02	+.01	+.04	+.01	+.04	+.09	.0039	.00270	.00432
		13 May '53	+.05	-.02	0	+.03	+.03	0	+.09	.0047		
	2	26 June '53	+.02	--	0	+.03	+.04	0	+.09	.0029	.00162	
2	3	22 July '53	+.03	+.01	0	-.04	+.03	-.01	+.02	.0036	.00006	.00008
	4	19 Aug. '53	+.04	0	+.03	-.06	0	0	+.01	.0061	.00001	
3	5	30 Oct. '53	-.02	-.03	+.03	-.01	-.02	-.04	-.09	.0043	.00135	.02575
	6	19 Nov. '53	-.02	-.06	+.04	-.01	0	-.02	-.07	.0061	.00081	
	7	28 Dec. '53	-.02	-.02	+.03	-.02	-.04	+.02	-.05	.0041	.00041	
	8	26 Jan. '54	+.02	-.03	+.04	+.01	-.02	-.01	+.01	.0035	.02175	
		27 Jan. '54	+.01	+.04	+.05	+.06	+.07	+.01	+.24	.0128		
		28 Jan. '54	+.04	+.02	+.06	+.06	+.05	+.04	+.27	.0133		
	9	29 Mar. '54	-.01	-.02	+.03	-.01	-.03	+.02	-.02	.0028	.00006	
	10	27 Apr. '54	-.03	-.04	+.03	+.02	-.05	+.01	-.06	.0064	.00060	
	11	14 May '54	+.04	+.03	+.02	+.07	+.02	+.02	+.20	.0086	.00666	
	12	18 June '54	0	-.03	+.03	+.03	+.02	+.02	+.07	.0035	.00081	
4	13	26 July '54	0	-.02	+.03	-.02	+.06	0	+.05	.0053	.00041	.00907
	14	16 Aug. '54	-.03	-.03	+.05	+.01	+.08	+.03	+.11	.0117	.00440	
		26 Aug. '54	+.03	-.04	+.01	0	+.07	+.05	+.12	.0100		
	15	1 Sep. '54	+.02	-.20	0	-.07	+.06	+.03	+.16	.0498	.00426	
5	16	4 Oct. '54	-.07	-.06	+.01	0	+.02	0	-.10	.0090	.00166	.09686
	17	15 Dec. '54	-.02	+.04	+.07	+.05	-.01	+.03	+.16	.0104	.01308	
		21 Dec. '54	+.03	+.05	+.06	+.02	+.05	+.02	+.23	.0103		
	18	25 Jan. '55	-.15	-.01	-.10	-.20	-.03	+.01	+.48	.0736	.03840	
	19	15 Feb. '55	+.06	0	+.07	-.20	+.02	+.07	+.02	.0538	.00006	
	20	10 Mar. '55	+.06	-.01	+.03	0	+.02	+.07	+.17	.0099	.00962	
		22 Mar. '55	+.03	0	+.06	-.01	+.02	+.07	+.17	.0099		
	21	6 Apr. '55	0	+.01	+.06	+.02	-.05	+.07	+.11	.0135	.02388	
		20 Apr. '55	+.04	+.02	+.07	+.08	-.05	+.01	+.17	.0159		
		29 Apr. '55	+.02	+.09	+.05	+.06	+.07	+.03	+.32	.0195		
	22	5 May '55	+.02	-.04	+.04	+.06	+.05	+.07	+.20	.0146	.00672	
		16 May '55	+.02	-.01	+.02	-.05	-.05	+.05	-.02	.0084		
	23	8 June '55	+.09	-.03	+.05	+.03	+.07	+.04	+.25	.0189	.01041	
6	24	6 July '55	+.14	+.01	+.03	+.10	+.08	+.07	+.43	.0419	.03081	.10087
	25	1 Aug. '55	+.11	+.01	+.04	+.05	+.06	+.12	+.39	.0343	.02535	
	26	10 Sep. '55	+.11	0	+.08	+.03	+.01	+.12	+.35	.0339	.02041	
	27	3 Oct. '55	+.06	0	+.09	+.02	+.05	+.03	+.25	.0155	.02442	
		12 Oct. '55	+.06	+.02	+.09	+.06	+.06	-.03	+.29	.0202		
	28	23 Nov. '55	+.05	-.02	+.06	+.07	+.05	+.05	+.26	.0164	.01126	
7	29	13 Jan. '56	+.06	+.01	+.03	+.04	+.06	+.09	+.29	.0179	.01508	.02266
		30 Jan. '56	+.03	-.01	+.02	+.04	+.01	-.01	+.08	.0032		
								Total	+4.43	.6144	.27707	.25961

$$\sum_h \left[\frac{(\Sigma_{ijk}x)^2}{N_i}\right] = \frac{(.27)^2}{17} + \frac{(.03)^2}{12} + \ldots \frac{(\Sigma_{ijk}x)^2}{N_i} = .14709$$

$$\frac{(\Sigma_{hijk}x)^2}{N_h} = \frac{(4.43)^2}{239} = .08211$$

Table 1. Analysis of variance for unequal samples of sand level change. Station at 70 ft depth.

Part B. Analysis of variance

	Between Rods	Within Months	Between Months	Between Seasons
Lower Level Sum	0.6144	0.27707	0.25961	0.14709
Higher Level Sum	0.27707	0.25961	0.14709	0.08211
Sum Squared Deviations	0.33733	0.01746	0.11252	0.06488
Degrees of Freedom	199	11	22	6
Mean Square	0.00169	0.00158	0.00511	0.01081
Lower Component		0.00169	0.00158	0.00511
Difference		-0.00011	0.00353	0.00570
Effective Subsample		5.97489	8.55393	31.52301
Component Estimate, s^2	0.00169	0	0.00041	0.00018
F		0.93491*	3.23417**	2.11545*

* Not significantly different from variations of shorter period.

** Significant at the 0.01 level; therefore highly significant.

$(\sigma_k^2 + k\,\sigma_j^2)$, where k is the known number of individuals which share in the particular sample value of this distribution (Olson and Potter, 1954, pp. 37-38).

The test of significance associated with the analysis of variance in this form is considered as the test of the hypothesis that the two mean squares σ_k^2 and $\sigma_k^2 + k\,\sigma_j^2$ are equal. This is equivalent to asking whether the contribution of σ_j^2 is equal to zero or whether there is a significant contribution to the mean square due to this factor σ_j^2. The F-test is used to test this hypothesis. The value of F is the ratio of the within months mean square to the between rods mean square; and, if this ratio exceeds the tabled values of F at a specified level of significance, then the hypothesis of equality of mean squares is rejected (Olson,and Potter, 1954, p. 38; Dixon and Massey, 1951, chap. 10; Snedecor, 1946, p. 231).

From the values in part B of table 1, the computed value of F is equal to 0.93491 and is less than 1. It is concluded therefore that the mean squares are approximately equal and that there is no significant contribution due to σ_j^2. If the F value exceeded the tabulated values (Dixon and Massey, 1951, pp. 310-313), the component estimate of σ_j^2 could have been computed from $\dfrac{(\sigma_k^2 + k\,\sigma_j^2) - \sigma_k^2}{k}$, as was the case for the other stations. In the present example, k is the effective subsample size. The reason for this is that the samples contributing to this mean square were not equal in size and k had to be computed as an effective subsample size. The effective subsample size is equal to 5.97489 and is computed from the following relation (Snedecor, 1946, pp. 234, 241):

$$k = \frac{\sum_j k - \dfrac{\sum_j (k)^2}{\sum_j k}}{(j-1)} \qquad (3)$$

This same procedure is followed for the next succeeding higher level of sampling to obtain the contribution in that group. In the present example, the difference happened to result in a minus value and it is concluded that the variance at this level, σ_j^2, is equal to zero. Since σ_j^2 should not be less than zero, this discrepancy may represent a sampling variation due to some unusually divergent measures in the rods (Olson and Potter, 1954, p. 40). The practical significance of this result is that the variability within months is negligible compared to the variability between rods.

Another way of estimating the variance among individual rod measures in an observation is to compute the pooled estimate or average variance.

The formula for this estimate is given by Dixon and Massey (1951, pp. 91-92) as

$$(4) \qquad s_p^{\,2} = \frac{(n_1-1)s_1^{\,2} + (n_2-1)s_2^{\,2} + \ldots + (n_k-1)s_k^{\,2}}{n_1 + n_2 + \ldots + n_k - k}$$

for k samples of variance. For the 70-foot station the pooled estimate of variance between rods is equal to 0.00169. The pooled estimate may be lower than that obtained in the analysis preceding because it is the average variance computed around each sample mean rather than around the mean of the group of all observations. It is felt that use of the pooled estimate is a better estimate for between rod variability. It is this value which has been used in obtaining the standard error discussed in the interpretation.

THE SIGN TEST FOR RUNS

The nonparametric sign test was used for determining the existence of a trend to the changes in sand level with time. This test does not involve the statistical parameters of the population distributions; it simply compares the distribution of values without specifying the form of the distributions (Dixon and Massey, 1951, p. 247). Furthermore, it is only necessary to assume that the observations represent a random sample.

For present purposes it was desired to know whether the changes in sand level with time had any cyclic trend or whether these changes were random. To test this, the procedure is to determine the median value of the ordered sequence of given mean values of sand level with time. All values above the median are then designated by a plus sign and all values below the median by a minus sign. The question is whether or not the positive values are distributed in a random manner among the negative values. The one or more adjacent similar signs are denoted as runs with the result that a run is started as soon as the sign changes (from plus to minus or from minus to plus). If the number of runs is very high, it would indicate a rapid periodic or cyclic trend. On the other hand, if the number of runs is very low, the sequence would be nearly monotonic (hence of slow period).

The test is based on the criterion for making one of three decisions for each group of observations (Hald, 1952, p. 749; Eisenhart, et al., 1947, p. 419).

(1) Accept the hypothesis that there is a trend.
(2) Reject the hypothesis of trend.
(3) Continue sampling. There may be a trend but the observations are not sufficiently refined to bring this trend out in the analysis.

Example of Sign Test from Station at 70-Foot Depth. The median is determined by taking the mean values of the raw data from Appendix ID and arranging these in order of increasing values. This median value is +.02. Now taking the original serial sequence and designating the values above the median as plus and the values below as minus, the following is obtained:

Sign	Run	Sign	Run
-	1	+	6
-		+	
-		-	7
-		-	
-		+	8
-		+	
-		-	9
-		+	10
-		+	
+	2	+	
+		-	11
-	3	+	12
-		+	
+	4	+	
-	5	+	
-		+	
-		+	
md.		+	
-		+	
-		-	13
			13

Number of items = 40
Total number of runs = 13

Table 11 in Dixon and Massey (1951, p. 325) shows that the upper limit of runs to be expected from a pure random arrangement is 27, while the lower limit to be expected is 14. Values either above or below these tabled values would not be expected to occur more than 2.5 per cent of the time; i.e., there is a risk of being wrong in the decision 2.5 per cent of the time. Since the number of observed runs lies below the lower limit, it is concluded that there is a trend and the number of runs is abnormally smaller than would be expected from a simple random variation of data.

ESTIMATES OF CORRELATION

In order to determine the relationship between changes in sand level from one station to another, estimates of the correlation between stations were made. The test used is designed to determine whether or not the changes between stations are independent of each other. If these changes are not independent, it is desirable to know whether the correlation between them is positive or negative; i.e., either there is simultaneous deposition of sand at the two stations in question, or there is deposition of sand at one station and erosion of sand at the other.

The relatively simple statistic used here to estimate the correlation is the tetrachoric r, described in Dixon and Massey (1951, pp. 233-235). The procedure is to make a graphic plot of one mean value of sand level against the other, for all mean values observed between the two stations on a simultaneous date. After all the values are plotted in this manner, the plotted points are divided equally by a horizontal line and a vertical line. If, then, the number of points in the upper right and lower left quadrants is greater than in the other two quadrants, the correlation is positive. If the opposite is true, the correlation is negative. This procedure is very useful in the exploratory stages of a study, such as the present one, to determine whether the factors are associated.

Example of Correlation between Stations at 70 and 30-Foot Depths. By taking the data from the table in Appendix IB and ID, and collecting all mean sand level changes observed on simultaneous dates for the 70 and 30-foot depth stations, the graphic plot of figure 10 is obtained. The total number of points in the plot is 26. Dividing these points by a horizontal and a vertical line so that an equal number of points lie above and below the horizontal line and an equal number of points lie on either side of the vertical line, the graphic plot is divided into four quadrants. The number of points in each of these quadrants is then designated by n_1, n_2, n_3, and n_4. The value of

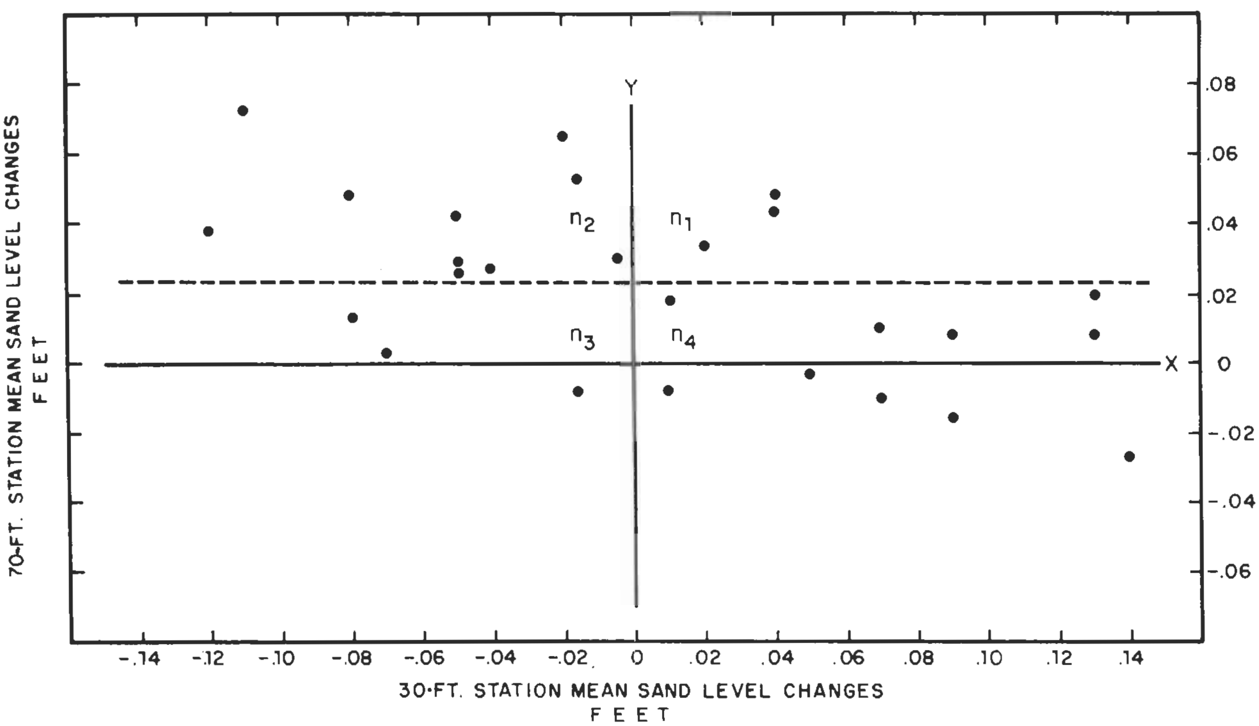
$$\frac{n_1 + n_3}{n_1 + n_2 + n_3 + n_4} \quad \text{or} \quad \frac{n_2 + n_4}{n_1 + n_2 + n_3 + n_4}$$

is then computed, whichever is larger. In this case the second relation is the larger and results in a value of 0.769. This value is then entered in figure 2 of Dixon and Massey (1951, p. 234) to obtain the estimate of correlation. The estimate arrived at from this procedure is -0.75 for the correlation coefficient. It is concluded that these stations are not independent of each other. The correlation is negative; i.e., when the sand is built up at one station, there is a loss at the other.

INTERPRETATION

Of the several distinct factors involved in a study of this kind, it is difficult to isolate the local irregularities of the bottom from those changes which are significant. That is, the local irregularities of the bottom may be as large as the net changes in sand level one is trying to measure. Consequently such irregularities may completely mask the minor changes in sand level. The primary purpose of the present study was an attempt to evaluate the magnitude of the separate factors of variability involved in sand level changes.

GRAPHIC ESTIMATE OF CORRELATION



Graphic method of estimating the correlation between sand levels at the 30 and 70-foot depth stations on D range.

FIGURE 10 · CORRELATION BETWEEN SAND LEVEL CHANGES AT THE 30 AND 70-FOOT DEPTHS

Another serious consideration which could be made is the factor of costs. One might spend the entire time in a survey by making a large number of very precise measures from day to day. If, however, the changes of major importance are not day to day occurrences, but monthly or yearly occurrences, it would be less costly to take fewer day to day measures and still get the desired information. Before making such decisions, it is necessary that the sources of variation and their magnitudes be evaluated. In studies where this is done, it is possible to better allocate or budget sampling time so that in the future more information can be arrived at with a smaller cost in time and effort (Eisenhart, et al., 1947, p. 269). Suggestions are made for better budgeting of sampling in the discussion to follow and in the conclusions.

Earlier studies have indicated that the major changes in sand level on the beaches and in adjacent shallow waters tend to be systematic and can be related to the character of wave motion, tidal cycles, and to seasonal variations representing the combined effects of tides and waves. Initially it was intended that an attempt be made to correlate the sand level changes at the four stations on D range directly with local wave and tide characteristics. However, the changes were smaller than anticipated and it early became apparent that one must look to more recondite parameters than can be extrapolated from simple wave parameters. Therefore no attempt was made to correlate day to day wave action with sand level changes, but rather a gross seasonal distinction based on wave height was made. Summer was arbitrarily defined as those months or portions of months during which significant breaker height exceeded 5 feet less than one-third of the time, and winter was defined as the intervening period during which the breaker height exceeded 5 feet more than one-third of the time. For this purpose the breaker height at the wave convergence zone near D range was selected. The envelope of the significant breaker heights is plotted as a function of time in figure 7 and the summer seasons are indicated.

SAND LEVEL CHANGES ON D RANGE

The major part of this study was devoted to a study of sand level changes on D range. The large number of measurements and the control afforded by this area allowed for a relatively rigorous statistical evaluation of sand level changes. The statistical methods used have already been outlined in the previous section. The results of these analyses are presented in Appendix I and II and are summarized in table 2.

Reliability of Reference Rod Measurements. An estimate of sand level at a given depth is the mean value of a group of measures and this mean value is dependent upon the local irregularities at that station. The precision with which the mean value estimates the sand level is dependent upon the magnitude of these local irregularities. The standard error is a measure of this precision and can be computed for one observation. However, a better estimate is to compute an average standard

Table 2. Summary of statistical results, D range.

Station Depth (ft)	Total Number of Surveys	Duration of Survey in Months	Standard Error of Measurement $SE = \frac{S}{\sqrt{n}}$ (ft)	Range in Mean Sand Level (ft)	Standard Deviation of Sand Level Changes (ft)			Cyclic Trend
					Within Months	Between Months	Between Seasons	
18	11	4	.061	.62	0.055	0.040*	--	--
30	45	32	.067	.29	0*	0.048	0.042	Seasonal
52	49	35	.050	.16	0.015*	0.003*	0.033	Yes**
70	40	33	.033	.15	0*	0.020	0.013*	Yes**

* Not significantly different from variations of shorter period.
** Cycles more frequent than seasonal, but less frequent than monthly.

Correlation Between Stations		
Between Stations	Estimated Correlation Coefficient	Statistically Significant
30 52	+0.36	Weak
30 70	-0.75	Yes
52 70	+0.60	Yes

error pooled from all observations. The standard errors computed for each station in this manner, from 18 feet to 70 feet, decrease progressively away from shore (table 2). This indicates that either the local bottom irregularities or the error in measuring, or both, decrease away from shore. It is believed that while conditions nearer shore made measurements somewhat more difficult, these influences are minor compared to the actual bottom irregularities. The average standard error of observation for the four stations is approximately 0.05 foot and is a confidence limit within which the mean sand level falls. This means that if the changes in sand level which one is trying to measure are of this order of magnitude, they will be masked by this error.

<u>Magnitude of Sand Level Changes</u>. The magnitude of the significant changes in sand level decreases with increasing depth and is found to be very small in depths of 30 feet and greater. The changes in sand level range from 0.15 foot at depths of 70 feet to values in excess of 0.6 foot in water depths of 18 feet (table 2). The results of the analysis of variance for the station at the depth of 18 feet are not valid for statistical inference between seasons because of the limited data[2]. However, these results give an order of magnitude of the variability within and between months.

For the other three stations on D range, there is a general decrease in the magnitude of the between season variability from station to station seaward. The component estimate of the between months variability at the 30-foot depth shows that there is a fluctuation of approximately 0.05 foot around the average level of sand, and indicates a range of about 0.10 foot for the changes. This range is equivalent to twice the standard deviation (table 2), where the standard deviation is the square root of the variance component. The estimate of the between months variation at the 70-foot depth is about half that at the 30-foot depth and the variation at the 52-foot depth is negligible.

The practical significance of the zero within months variation at the 30 and 70-foot depths and the negligible variation at the 52-foot depth is that the within months variations here are very small relative to the between rods variation (table 2). Therefore these variations are masked by the variation which takes place between rods. Consequently, it is apparent that more frequent measures in time would have to be made before these within month effects could be isolated and evaluated.

The results in the analysis of trend indicate that the changes in sand level are not random but cyclic in nature (table 2). The test used,

[2] The reference rods at this station were lost following a series of high waves in November, 1953. Acoustic soundings at this station indicated an erosion of sand of 2 feet.

however, is by nature not efficient for indicating seasonal trends in the presence of pronounced variations of shorter period. Thus, for example, at the 30-foot station, there is a trend in sand level with season which could be observed on the graph (figure 1), and which is further indicated by the average sand level height for each season (table 3), but which did not show up in the trend test. For this station the sand level tends to be high (deposition) during the summer and low (erosion) during the winter. The deeper stations did not show measurable seasonal trends, of cyclic nature but they did show shorter period cycles.

Correlation of Sand Level Changes between Stations. It was desirable to know whether or not the changes in sand level between the various stations were related. The estimates of correlation previously described indicated (as in the example shown) that the correlation between the 70-foot station and the 30-foot station was inverse (or negative). That is, when sand was eroded at the 70-foot station, there was deposition at the 30-foot station; and, conversely, when there was deposition at the 70-foot station, there was erosion of sand at the 30-foot station. Between the 70-foot and the 52-foot depths there was a positive correlation; when sand was deposited at the 70-foot station, it was also built up at the 52-foot station. Between the 30-foot station and the 52-foot station, however, there was no strong correlation.

The fairly strong negative correlation between changes in sand level at the 30 and 70-foot depths, the somewhat weaker positive correlation between the 52 and 70-foot depths, and the very weak correlation between the 30 and 52-foot depths suggests that changes at the 52-foot station are transitional or borderline. That is to say, erosion at the 30-foot level is frequently accompanied by deposition at the 70-foot level and may or may not be accompanied by deposition at the 52-foot level.

No attempt was made to correlate the changes at the 18-foot depth with the other stations. The reason for this was that the number of observations from the 18-foot station was very limited in extent and did not allow for estimates of correlation.

Sand Size. A sample of the bottom sediment was obtained by the swimmers during each of the surveys on D range. The size distribution characteristics of the samples are listed in Appendix IIIA-B. The method of analysis and a detailed description of the character and composition of sediments obtained in this area during 1949 and 1950 are given in Inman, 1953.

The median diameter of the sediments averaged about 150 microns at the 18-foot depth, 120 microns at the 30-foot depth and 110 microns at the 52 and 70-foot depths. The size of the sand remained relatively constant at the three deeper stations during the first 18 months of the study, but fluctuated erratically during several periods beginning in

Table 3. Seasonal average of sand levels, D range.

Season	Station at 30-ft. depth		Station at 52-ft. depth		Station at 70-ft. depth	
	Number of Surveys	Average Sand Level (ft)	Number of Surveys	Average Sand Level (ft)	Number of Surveys	Average Sand Level (ft)
Winter 1952-1953	1	+.03	5	-.01	3	+.02
Summer 1953	9	+.02	5	-.01	2	0
Winter 1953-1954	12	0	14	+.04	10	+.01
Summer 1954	5	+.12	6	+.08	5	0
Winter 1954-1955	13	-.05	11	+.05	12	+.02
Summer 1955	2	+.01	5	+.07	5	+.06
Winter 1955-1956	3	-.04	3	+.08	3	+.03
Average Summer	16	+.05	16	+.05	12	+.02
Average Winter	29	-.02	33	+.04	28	+.02
Mean Sand Level	45	0	49	+.04	40	+.02

December, 1954. No simple correlation between sand size and sand level change was observed, although the large changes in sand size were commonly associated with greater than usual changes in sand level.

SAND LEVEL CHANGES ON B RANGE

The sand level changes associated with the tidal cycle were measured by placing a series of reference rods at intervals of 20 feet along a profile extending through the surf zone and onto the beach foreshore on B range. Three series of surveys, each consisting of a high-tide profile followed by a profile during the succeeding low tide, were made. The differences in sand level between tidal cycles within a day and the differences in level between days are shown in figure 8. The surveys were made during spring tides with ranges from high to low water level of about 6 feet. The significant breaker heights ranged from about 2 to 4 feet (Appendix IV).

Although these surveys represent a very small sample, there is some indication of systematic changes in profile related to the position of high and low tide breaker zones. All three survey series show deposition on the upper portions of the beach foreshore between the high and the following low tide, and the two October surveys show a tendency for a bar and trough to form in the zone of low tide breakers. It is interesting to note that for these surveys the magnitude of sand level change between high and low tide was one-half as great as the magnitude of the total change for the two-week period between the first and second surveys.

Several of the seaward reference rods have remained in position for over two years. They are completely covered with sand each winter and bared again for short periods during summer when the sand migrates landward and is deposited on the beach foreshore. The summer fluctuations in sand level at the deepest station on B range, approximately 6 feet below MLLW, are graphed together with the changes on D range in figure 7.

Experience indicated that accurate measurement of reference rods was limited to surf conditions where the breaking waves did not exceed 5 feet in height. For such conditions it is estimated that the accuracy of measurement is of the order of ±0.05 foot. This is the same order of magnitude as the standard error in level obtained for the deeper water stations on D range, which was based on the measurement of six rods. The similarity in the magnitude of error results from differences in the nature of the problem on the two ranges. The problem on D range was to determine the mean level for an area from six measurements of an irregular bottom, while on B range the interest was on the sand level at the position of a single reference rod.

ACOUSTIC SOUNDING

The evaluation of the accuracy of the acoustic method of hydrographic survey was one of the objectives of the investigation. It has been demonstrated that depths obtained by echo sounding are reproducible when repeated soundings are made during the same day (Shepard and Inman, 1951; Saville and Caldwell, 1953). This finding resulted in optimism in the estimation of the reliability of hydrographic surveys. In the previous studies comparison of sounding data over periods longer than a day could not be used to evaluate the reliability of the method because of the uncertainty in the amount of true change in sand level.

The total or compounded errors involved in reducing an uncorrected sounding to some absolute datum can be roughly divided into errors incurred in (1) measuring the instantaneous depth of water, (2) positioning, and (3) resolving the corrected depth to datum. For convenience these errors are listed in outline form in table 4. Inspection of this table shows that many of the factors leading to error tend to remain constant during the course of a single survey; wave and tide conditions are similar, the same operator bias is in effect, etc. On the other hand, day to day observations may involve differences in personnel, state of the sea, and instrument characteristics. Near the surf zone, surf beat (Munk, 1949) may produce fluctuations of sea level, of the order of one-tenth of the wave height, which are not coherent over the area of the survey. Also, so subtle a factor as moisture of the fathogram paper can change the degree of halation and clarity of the trace and hence the accuracy of the fathogram.

A series of echo sounding surveys were conducted concurrent with the reference rod measurements on station D. In general, five echo sounding runs were made on each station and the data from these reduced in the manner described previously. The mean values of each day's observations from the station at the 30-foot depth are shown together with the results from the reference rod measurements in figure 9. For purposes of illustration, a value of the reference level was assumed such that the depths from the acoustic sounding and from the reference rod measurements coincided on the first day of the comparison, 23 July 1953.

It is apparent from figure 9 that the daily ranges in acoustic soundings and reference rods were relatively small, the scatter of acoustic sounding being in general three to four times greater than that of the reference rods. However, the day to day or the survey to survey variation in acoustic soundings is much greater than that for the reference rods. If it is assumed that the reference rods give a reliable measure of the real changes in sand level, then it can be concluded that the accuracy of the acoustic method of survey under these experimental conditions is of the order of $\pm \frac{1}{2}$ foot. Similar accuracy was obtained for the stations of 52 and 70-foot depths.

Table 4. Outline of factors leading to error in the reduction of acoustic sounding data to basic datum.

1. Errors in measuring depth.
    a. Calibration of instrument
    b. Stability of instrument
    c. Background noise: wave conditions, clarity of record
    d. Operator variables: control of gain, frequency and power of sounder, systematic errors in reading record.
2. Errors in positioning.
    a. Operator errors
    b. State of sea; pitch and roll of vessel
    c. Slope of bottom
3. Errors in correcting measured depth to absolute datum (from tide gage).
    a. Background noise of tide record: waves, clarity of record
    b. Anomalies in recorded level: water level change in tide well caused by water velocity against orifice, etc.
    c. Incoherent changes in sea level: surf beat, surges, etc.

SUMMARY AND CONCLUSIONS

1. A technique was developed for establishing a reference level on the bottom from which small net changes in sand level of the sand could be measured. The reference level was established by forcing six rods into the sandy bottom and then the changes in sand level were based upon the differences in lengths of rod exposed from survey to survey. Measurements, which were made by swimmers equipped with self-contained underwater breathing apparatus, resulted in a standard error of about ±0.05 foot per survey.

2. The total range in sand level probably exceeds 2 feet at the 18-foot deep station and changes in excess of 0.6 foot were measured before the reference rods were lost. The range decreases with increasing depth; ranges in net sand level of 0.29, 0.16, and 0.15 foot were measured at stations where the depth of water was 30, 52, and 70 feet respectively.

3. Statistical evaluation of sand level changes demonstrates that there is a general decrease in the magnitude of the variability in sand level from station to station seaward. This implies that the local bottom irregularities at each station (as measured by the variability between the six reference rods), as well as the frequency and magnitude of net change in sand level at the station, decrease with increasing depth.

4. A seasonal trend in sand level change was observed at the station at 30-foot depth where the sand level was high in the summer and low in the winter. At the deeper stations, 52 and 70 feet, seasonal trends were masked by fluctuations of shorter period.

5. There is a significant correlation between changes in sand level from stations at various depths. Changes at one depth are accompanied by changes at another; and, their relation may be direct or inverse, depending upon the stations involved.

6. A comparison of sand level changes between tidal cycles, obtained from reference rods placed along a traverse through the surf zone, showed systematic changes to occur in the beach profile near the position of high and low tide breaker zones. For the six surveys, the magnitude of sand level change between high and low tide was approximately one-half as great as the total change during the two week period.

7. Comparison of acoustic soundings with reference rod measurements indicated that the day to day accuracy of the acoustic sounding method was of the order of $\pm \frac{1}{2}$ foot, although soundings during one day of survey operation may be relatively precise in terms of reproducibility.

ACKNOWLEDGEMENTS

The field phase of the investigation was largely the work of Earl Murray, who was in charge of the boat and made all of the reference rod measurements. Assistance in the field work and analysis of data was given by Jean Short, and assistance with illustrations was given by Robert C. Winsett. Valuable suggestions and guidance during the course of the study were contributed by Robert S. Arthur, Jeffrey D. Frautschy, George F. McEwen, Robert L. Miller and J. S. Kahn.

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APPENDIX IA-ID

Deviations of Individual Rod Measurements from Their Reference Level, D Range

IA Station at 18-ft. depth

IB Station at 30-ft. depth

IC Station at 52-ft. depth

ID Station at 70-ft. depth

APPENDIX IA - STATION AT 18-FT. DEPTH

DATE	DIFFERENCE FROM REFERENCE LEVEL IN FT.						MEAN	STANDARD DEVIATION
	Rod 1	Rod 2	Rod 3	Rod 4	Rod 5	Rod 6	$\bar{x}$	s
10 July '53	+.04	+.13	+.08	+.06	+.04	+.04	+.06	.036
17 July '53	-.04	-.01	+.02	-.03	+.01	-.03	-.01	.088
23 July '53	-.08	-.01	-.09	-.05	-.07	-.12	-.07	.037
27 July '53	-.07	-.06	-.09	-.08	-.04	-.11	-.08	.024
12 Aug. '53	-.09	-.07	-.07	-.05	-.07	--	-.07	.014
14 Aug. '53	-.11	-.06	-.06	-.12	-.06	--	-.08	.030
25 Aug. '53	-.13	-.09	-.08	-.16	-.18	--	-.13	.043
31 Aug. '53	-.10	-.12	-.12	-.12	-.22	--	-.14	.048
11 Sep. '53	-.18	-.13	-.08	-.08	-.12	--	-.12	.041
15 Oct. '53	-.48	-.38	-.39	-.37	-.48	--	-.42	.055
21 Oct. '53	-.56	-.44	-.52	-.47	-.80	--	-.56	.143

APPENDIX IB - STATION AT 30-FT. DEPTH

DATE	DIFFERENCE FROM REFERENCE LEVEL IN FT.						MEAN	STANDARD DEVIATION
	Rod 1	Rod 2	Rod 3	Rod 4	Rod 5	Rod 6	$\bar{x}$	s
22 June '53	+.02	+.05	+.03	+.05	+.01	0	+.03	.020
7 July '53	0	--	+.04	+.10	+.05	+.03	+.04	.037
23 July '53	-.08	-.02	+.01	-.03	+.02	-.04	-.02	.037
27 July '53	0	+.03	-.01	+.02	-.02	-.02	0	.021
5 Aug. '53	-.06	+.02	0	+.03	+.01	+.04	+.01	.036
12 Aug. '53	+.01	+.05	+.03	+.08	+.01	+.02	+.04	.027
21 Aug. '53	-.02	-.01	-.04	+.01	-.08	-.03	-.02	.030
25 Aug. '53	+.06	+.05	+.08	+.08	+.03	0	+.05	.031
31 Aug. '53	-.01	+.06	-.05	+.07	-.01	+.04	+.02	.047
11 Sep. '53	+.02	+.07	+.07	+.04	+.03	+.01	+.04	.025
15 Oct. '53	-.06	-.03	-.04	0	-.09	-.03	-.04	.030
21 Oct. '53	-.08	-.03	-.08	+.03	-.06	-.02	-.04	.042
16 Nov. '53	-.21	-.12	-.15	-.11	-.21	-.08	-.15	.054
28 Dec. '53	+.01	+.02	+.02	+.09	-.07	-.03	+.01	.054
5 Jan. '54	-.02	+.01	0	+.04	-.04	-.04	-.01	.031

APPENDIX IB - 2

DATE	DIFFERENCE FROM REFERENCE LEVEL IN FT.						MEAN	STANDARD DEVIATION
	Rod 1	Rod 2	Rod 3	Rod 4	Rod 5	Rod 6	$\bar{x}$	s
22 Jan. '54	-.01	+.04	-.02	+.03	-.05	-.07	-.01	.043
2 Feb. '54	-.03	-.02	-.02	-.02	-.07	-.02	-.03	.020
29 Mar. '54	+.02	0	+.20	+.04	+.01	0	+.05	.077
27 Apr. '54	+.11	+.08	+.20	+.09	+.04	-.08	+.07	.092
14 May '54	-.17	+.08	-.05	+.16	-.06	+.02	0	.116
18 June '54	+.08	+.19	+.01	+.16	+.03	-.06	+.07	.095
28 June '54	+.09	-.08	+.22	+.13	+.06	+.04	+.08	.099
26 July '54	+.11	+.10	+.28	+.13	+.08	+.07	+.13	.077
16 Aug. '54	+.02	+.10	+.22	+.11	+.06	0	+.09	.079
26 Aug. '54	+.06	+.15	+.25	+.14	+.07	+.07	+.13	.073
1 Sep. '54	+.12	+.16	+.24	+.16	+.08	+.06	+.14	.065
4 Oct. '54	+.11	+.10	+.24	-.04	+.03	+.05	+.09	.094
15 Dec. '54	-.05	-.03	+.11	-.09	-.07	-.16	-.05	.089
20 Dec. '54	-.10	-.05	+.04	--	-.09	-.17	-.07	.077
21 Dec. '54	-.08	--	--	--	-.19	-.09	-.12	.060

APPENDIX IB - 3

DATE	DIFFERENCE FROM REFERENCE LEVEL IN FT.						MEAN	STANDARD DEVIATION
	Rod 1	Rod 2	Rod 3	Rod 4	Rod 5	Rod 6	$\bar{x}$	S
25 Jan. '55	-.05	0	+.10	-.04	-.02	-.09	-.02	.065
15 Feb. '55	-.05	-.07	+.05	-.06	-.17	-.12	-.07	.074
10 Mar. '55	-.07	-.05	+.08	-.07	-.07	-.10	-.05	.064
22 Mar. '55	-.05	-.04	+.10	-.07	-.06	-.13	-.04	.077
6 Apr. '55	-.03	-.01	+.12	+.01	0	-.03	+.01	.056
29 Apr. '55	-.02	-.03	+.10	-.05	-.01	-.09	-.02	.064
5 May '55	-.01	+.02	+.15	+.09	-.07	-.05	+.02	.084
17 May '55	-.07	-.03	0	-.03	-.06	-.09	-.04	.033
8 June '55	-.07	-.15	+.12	0	--	-.15	-.05	.118
6 July '55	-.10	-.07	+.01	-.05	-.15	-.31	-.11	.110
1 Aug. '55	-.05	+.03	+.03	-.04	-.04	-.04	-.02	.038
12 Oct. '55	-.10	-.01	+.23	+.07	+.09	-.07	+.04	.121
23 Nov. '55	-.03	+.05	+.20	0	-.01	+.05	+.04	.083
13 Jan. '56	-.14	-.11	-.03	-.09	-.02	-.12	-.08	.048
30 Jan. '56	-.12	-.12	+.05	-.13	-.09	-.10	-.08	.068

APPENDIX IC - STATION AT 52-FT. DEPTH

DATE	DIFFERENCE FROM REFERENCE LEVEL IN FT.						MEAN	STANDARD DEVIATION
	Rod 1	Rod 2	Rod 3	Rod 4	Rod 5	Rod 6	$\bar{x}$	s
11 Mar. '53	-.01	-.01	-.01	-.01	-.07	-.02	-.02	.024
18 Mar. '53	-.01	-.01	-.02	+.01	+.01	-.05	-.01	.022
31 Mar. '53	0	0	-.02	0	0	-.05	-.01	.020
4 May '53	+.04	-.01	-.02	+.01	-.01	-.04	-.01	.027
24 June '53	+.04	-.03	-.03	+.04	-.03	--	0	.038
10 July '53	+.04	-.03	0	+.02	-.01	-.08	-.01	.042
17 July '53	+.04	-.01	0	+.02	-.06	-.09	-.02	.049
5 Aug. '53	-.03	-.04	0	0	-.08	-.14	-.05	.054
14 Aug. '53	+.05	-.02	+.03	+.02	-.02	-.08	0	.047
21 Aug. '53	+.10	+.03	+.09	+.05	0	-.04	+.04	.053
20 Oct. '53	+.05	0	-.03	+.08	-.05	-.08	-.01	.061
23 Oct. '53	+.06	0	0	+.15	-.03	-.05	+.02	.073
16 Nov. '53	+.03	-.01	+.02	+.09	-.01	-.12	0	.069
19 Nov. '53	-.01	-.01	+.05	+.05	+.04	-.07	+.01	.047
23 Nov. '53	0	-.01	+.04	+.09	+.04	-.07	+.02	.055
28 Dec. '53	0	0	+.01	+.08	+.05	-.04	+.02	.042

APPENDIX IC - 2

DATE	DIFFERENCE FROM REFERENCE LEVEL IN FT. Rod 1	Rod 2	Rod 3	Rod 4	Rod 5	Rod 6	MEAN $\bar{x}$	STANDARD DEVIATION s
14 Jan. '54	+.01	+.01	+.03	+.02	-.03	-.03	0	.018
21 Jan. '54	+.09	+.04	+.04	+.13	+.05	+.02	+.06	.040
28 Jan. '54	+.17	+.07	+.10	+.15	+.04	+.05	+.10	.053
29 Mar. '54	--	+.03	-.01	+.12	+.05	+.09	+.06	.051
27 Apr. '54	--	-.01	-.01	+.11	+.09	-.01	+.03	.060
14 May '54	--	+.03	+.07	+.15	+.12	+.07	+.09	.047
18 June '54	--	+.13	-.01	+.02	+.07	-.02	+.04	.062
28 June '54	--	+.05	+.09	+.13	+.13	+.02	+.08	.049
26 July '54	--	+.07	+.09	+.13	+.09	+.03	+.08	.036
16 Aug. '54	--	+.06	+.08	+.17	+.11	+.01	+.09	.059
26 Aug. '54	--	+.03	+.07	+.15	+.09	+.02	+.05	.052
1 Sep. '54	--	+.03	+.06	+.15	+.09	+.07	+.06	.045
28 Sep. '54	--	+.09	+.07	+.11	+.05	0	+.06	.042
4 Oct. '54	--	+.05	+.09	+.13	+.06	+.22	+.11	.069
15 Dec. '54	--	-.02	+.04	+.12	+.04	-.05	+.03	.065

APPENDIX IC - 3

DATE	DIFFERENCE FROM REFERENCE LEVEL IN FT. Rod 1	Rod 2	Rod 3	Rod 4	Rod 5	Rod 6	MEAN $\bar{x}$	STANDARD DEVIATION s
21 Dec. '54	--	+.04	+.07	+.08	+.08	-.01	+.05	.038
25 Jan. '55	--	0	+.09	+.11	-.01	+.05	+.05	.053
15 Feb. '55	--	+.02	+.07	+.07	-.01	+.01	+.03	.036
10 Mar. '55	--	+.05	+.05	+.11	+.06	+.01	+.06	.036
22 Mar. '55	--	+.04	+.09	+.21	+.10	+.02	+.09	.074
6 Apr. '55	--	-.01	+.07	+.17	+.05	-.04	+.05	.081
29 Apr. '55	--	+.04	-.03	+.07	+.08	-.05	+.02	.059
5 May '55	--	+.09	+.02	+.12	+.12	+.05	+.08	.044
17 May '55	--	0	+.04	+.12	+.09	+.08	+.07	.047
8 June '55	--	0	+.05	+.10	+.07	+.09	+.06	.040
6 July '55	--	-.01	+.12	+.12	+.07	+.02	+.04	.059
1 Aug. '55	--	+.03	+.12	+.16	+.06	+.04	+.08	.056
10 Sep. '55	--	+.07	+.02	+.06	+.10	+.06	+.06	.029

APPENDIX IC - 4

DATE	DIFFERENCE FROM REFERENCE LEVEL IN FT.						MEAN	STANDARD DEVIATION
	Rod 1	Rod 2	Rod 3	Rod 4	Rod 5	Rod 6	$\bar{x}$	s
3 Oct. '55	--	+.10	+.02	+.14	+.12	-.03	+.07	.072
12 Oct. '55	--	+.09	+.13	+.07	+.05	+.11	+.09	.032
23 Nov. '55	--	+.04	+.09	+.18	+.13	+.06	+.10	.056
13 Jan. '56	--	+.07	+.05	+.17	+.09	+.05	+.09	.050
30 Jan. '56	--	+.04	+.01	+.07	+.01	+.13	+.05	.050

APPENDIX ID - STATION AT 70-FT. DEPTH

DATE			DIFFERENCE FROM REFERENCE LEVEL IN FT.						MEAN	STANDARD DEVIATION
			Rod 1	Rod 2	Rod 3	Rod 4	Rod 5	Rod 6	$\bar{x}$	s
4	May	'53	+.01	-.02	+.01	+.04	+.01	+.04	+.02	.022
13	May	'53	+.05	-.02	0	+.03	+.03	0	+.02	.026
26	June	'53	+.02	--	0	+.03	+.04	0	+.02	.018
22	July	'53	+.03	+.01	0	-.04	+.03	-.01	0	.026
19	Aug.	'53	+.04	0	+.03	-.06	0	0	0	.034
30	Oct.	'53	-.02	-.03	+.03	-.01	-.02	-.04	-.02	.024
19	Nov.	'53	-.02	-.06	+.04	-.01	0	-.02	-.01	.032
28	Dec.	'53	-.02	-.02	+.03	-.02	-.04	+.02	-.01	.027
26	Jan.	'54	+.02	-.03	+.04	+.01	-.02	-.01	0	.026
27	Jan.	'54	+.01	+.04	+.05	+.06	+.07	+.01	+.04	.025
28	Jan.	'54	+.04	+.02	+.06	+.06	+.05	+.04	+.04	.015
29	Mar.	'54	-.01	-.02	+.03	-.01	-.03	+.02	0	.023
27	Apr.	'54	-.03	-.04	+.03	+.02	-.05	+.01	-.01	.034
14	May	'54	+.04	+.03	+.02	+.07	+.02	+.02	+.03	.020

APPENDIX ID - 2

DATE	DIFFERENCE FROM REFERENCE LEVEL IN FT.						MEAN	STANDARD DEVIATION
	Rod 1	Rod 2	Rod 3	Rod 4	Rod 5	Rod 6	$\bar{x}$	s
18 June '54	0	-.03	+.03	+.03	+.02	+.02	+.01	.023
26 July '54	0	-.02	+.03	-.02	+.06	0	+.01	.031
16 Aug. '54	-.03	-.03	+.05	+.01	+.08	+.03	+.02	.044
26 Aug. '54	+.03	-.04	+.01	0	+.07	+.05	+.02	.039
1 Sep. '54	+.02	-.20	0	-.07	+.06	+.03	-.03	.095
4 Oct. '54	-.07	-.06	+.01	0	+.02	0	-.02	.038
15 Dec. '54	-.02	+.04	+.07	+.05	-.01	+.03	+.03	.035
21 Dec. '54	+.03	+.05	+.06	+.02	+.05	+.02	+.04	.017
25 Jan. '55	-.15	-.01	-.10	-.20	-.03	+.01	-.08	.084
15 Feb. '55	+.06	0	+.07	-.20	+.02	+.07	0	.103
10 Mar. '55	+.06	-.01	+.03	0	+.02	+.07	+.03	.032
22 Mar. '55	+.03	0	+.06	-.01	+.02	+.07	+.03	.032
6 Apr. '55	0	+.01	+.06	+.02	-.05	+.07	+.02	.048
20 Apr. '55	+.04	+.02	+.07	+.08	-.05	+.01	+.03	.047
29 Apr. '55	+.02	+.09	+.05	+.06	+.07	+.03	+.05	.022
5 May '55	+.02	-.04	+.04	+.06	+.05	+.07	+.03	.040

APPENDIX ID - 3

DATE		DIFFERENCE FROM REFERENCE LEVEL IN FT.						MEAN	STANDARD DEVIATION
		Rod 1	Rod 2	Rod 3	Rod 4	Rod 5	Rod 6	$\bar{x}$	s
16 May	'55	+.02	-.01	+.02	-.05	-.05	+.05	0	.041
8 June	'55	+.09	-.03	+.05	+.03	+.07	+.04	+.04	.041
6 July	'55	+.14	+.01	+.03	+.10	+.08	+.07	+.07	.047
1 Aug.	'55	+.11	+.01	+.04	+.05	+.06	+.12	+.06	.042
10 Sep.	'55	+.11	0	+.08	+.03	+.01	+.12	+.06	.052
3 Oct.	'55	+.06	0	+.09	+.02	+.05	+.03	+.04	.032
12 Oct.	'55	+.06	+.02	+.09	+.06	+.06	-.03	+.05	.035
23 Nov.	'55	+.05	-.02	+.06	+.07	+.05	+.05	+.04	.032
13 Jan.	'56	+.06	+.01	+.03	+.04	+.06	+.09	+.05	.028
30 Jan.	'56	+.03	-.01	+.02	+.04	+.01	-.01	+.01	.020

APPENDIX IIA - IID

Summary

Analysis of Variance, D Range

IIA Station at 18-ft. depth

IIB Station at 30-ft. depth

IIC Station at 52-ft. depth

IID Station at 70-ft. depth
(see table 1, part B)

APPENDIX IIA - STATION AT 18-FT DEPTH

SUMMARY

ANALYSIS OF VARIANCE

	Between Rods	Within Months	Between Months
Lower Level Sum	3.00760	2.83052	2.69021
Higher Level Sum	2.83052	2.69021	2.60412
Sum Squared Deviations	0.17708	0.14031	0.08609
Degrees of Freedom	48	7	2
Mean Square	0.00368	0.02004	0.04305
Lower Component		0.00368	0.02004
Difference		0.01636	0.02301
Effective Subsample		5.42857	14.28571
Component Estimate, s^2	0.00368	0.00301	0.00161
F		5.44565**	2.15019*

* Not significantly different from variations of shorter period.

** Significant at the 0.01 level; therefore highly significant.

APPENDIX IIB - STATION AT 30-FT DEPTH

SUMMARY

ANALYSIS OF VARIANCE

	Between Rods	Within Months	Between Months	Between Seasons
Lower Level Sum	2.06310	1.04648	0.99129	0.52808
Higher Level Sum	1.04648	0.99129	0.52808	0.00057
Sum Squared Deviations	1.01662	0.05519	0.46321	0.52751
Degrees of Freedom	219	16	22	6
Mean Square	0.00464	0.00344	0.02105	0.08791
Lower Component		0.00464	0.00344	0.02105
Difference		-0.00120	0.01761	0.06686
Effective Subsample		5.86570	7.52719	37.39962
Component Estimate, S^2	0.00464	0	0.00233	0.00178
F		0.74137*	6.11918**	4.17624**

* Not significantly different from variations of shorter period.

** Significant at the 0.01 level; therefore highly significant.

APPENDIX IIC - STATION AT 52-FT DEPTH

SUMMARY

ANALYSIS OF VARIANCE

	Between Rods	Within Months	Between Months	Between Seasons
Lower Level Sum	1.39220	0.84612	0.77338	0.68151
Higher Level Sum	0.84612	0.77338	0.68151	0.43288
Sum Squared Deviations	0.54608	0.07274	0.09187	0.24863
Degrees of Freedom	214	19	23	6
Mean Square	0.00255	0.00382	0.00399	0.04143
Lower Component		0.00255	0.00382	0.00399
Difference		0.00127	0.00017	0.03744
Effective Subsample		5.25692	8.69122	34.68441
Component Estimate, S^2	0.00255	0.00024	0.00001	0.00107
F		1.49803*	1.04450*	10.38345**

* Not significantly different from variations of shorter period.

** Significant at the 0.01 level; therefore highly significant.

APPENDIX IID - Station at 70-ft. depth

See table 1, part B (page 15)

APPENDIX IIIA - IIID

Sediment Size, D Range

IIIA Station at 18-ft. depth

IIIB Station at 30-ft. depth

IIIC Station at 52-ft. depth

IIID Station at 70-ft. depth

APPENDIX IIIA- STATION AT 18-FT. DEPTH

Date	Median Diameter in Microns	Phi Size Distribution Measures*		
		Median Diameter Md_ϕ	Deviation Measure σ_o	Skewness Measure α_o
17 July '53	153	2.71	.38	-.03
23 July '53T	146	2.78	.38	-.05
23 July '53C	154	2.70	.38	-.05
12 Aug. '53	146	2.78	.42	-.05
14 Aug. '53	145	2.79	.40	-.05
25 Aug. '53	152	2.72	.45	0
31 Aug. '53	151	2.73	.42	-.07
11 Sep. '53	147	2.77	.42	-.07
15 Oct. '53	157	2.67	.38	-.03
21 Oct. '53	137	2.87	.45	-.09

* The phi size-distribution measures (Inman, 1952) are defined as:

$$Md_\phi = \phi_{50}$$

$$\sigma_o = \tfrac{1}{2}(\phi_{84} - \phi_{16})$$

$$\alpha_o = \frac{M_\phi - Md_\phi}{\sigma_o}$$

where $M_\phi = \frac{1}{2}(\phi_{16} + \phi_{84})$ is the phi mean diameter and ϕ_{16}, ϕ_{50}, and ϕ_{84} are diameters in phi units corresponding to the 16th, 50th, and 84th percentiles of the cumulative weight - percent (coarser) curve. $\phi = -\log_2$ (diameter in millimeters).

APPENDIX IIIB- STATION AT 30-FT. DEPTH

Date	Median Diameter in Microns	Phi Size Distribution Measures*		
		Median Diameter Md_ϕ	Deviation Measure $\sigma\phi$	Skewness Measure $\alpha\phi$
23 July '53	124	3.01	.46	-.06
27 July '53	117	3.09	.46	-.07
5 Aug. '53	120	3.06	.47	-.11
12 Aug. '53	117	3.10	.46	-.04
21 Aug. '53	118	3.08	.48	-.04
25 Aug. '53	124	3.01	.48	-.02
31 Aug. '53	128	2.96	.47	-.04
15 Oct. '53	126	2.99	.50	-.02
16 Nov. '53	114	3.13	.47	-.17
28 Dec. '53	117	3.10	.50	-.12
5 Jan. '54	122	3.04	.55	-.13
22 Jan. '54	136	2.88	.47	-.02
2 Feb. '54	124	3.01	.47	-.02
27 Apr. '54	127	2.98	.51	-.06
14 May '54	122	3.03	.45	-.07
18 June '54	121	3.05	.45	-.07
28 June '54	117	3.10	.51	0
26 July '54	117	3.10	.46	0
16 Aug. '54	121	3.05	.46	-.07
26 Aug. '54	115	3.12	.44	-.02
1 Sep. '54	118	3.08	.45	-.06
28 Sep. '54	120	3.06	.45	0
4 Oct. '54	122	3.04	.47	-.10

Date	Microns	Md_ϕ	σ_ϕ	α_ϕ
15 Dec. '54	118	3.08	.48	-.02
20 Dec. '54	138	2.86	.47	+.04
21 Dec. '54	125	3.00	.47	+.04
25 Jan. '55	103	3.28	.40	-.10
15 Feb. '55	115	3.12	.48	-.12
10 Mar. '55	128	2.96	.42	-.11
22 Mar. '55	115	3.12	.50	-.04
6 Apr. '55	113	3.14	.45	-.30
29 Apr. '55	125	3.00	.45	-.04
5 May '55	129	2.95	.44	-.02
17 May '55	122	3.03	.45	-.07
8 June '55	115	3.12	.40	-.05
6 July '55	122	3.03	.41	-.10
1 Aug. '55	144	2.80	.45	0
12 Oct. '55	125	3.00	.42	+.05
23 Nov. '55	113	3.14	.45	-.22
13 Jan. '56	127	2.98	.50	-.04
30 Jan. '56	109	3.20	.48	-.30

APPENDIX IIIC- STATION AT 52-FT. DEPTH

Date	Median Diameter in Microns	Phi Size Distribution Measures*		
		Median Diameter Md_ϕ	Deviation Measure σ_ϕ	Skewness Measure α_ϕ
10 July '53	106	3.24	.39	-.15
5 Aug. '53	107	3.23	.42	-.12
20 Oct. '53	102	3.29	.38	-.13
16 Nov. '53	102	3.29	.38	-.08
19 Nov. '53	106	3.24	.38	-.05
28 Dec. '53	102	3.30	.36	-.17
14 Jan. '54	105	3.25	.42	-.14
28 Jan. '54	106	3.24	.38	-.10
29 Mar. '54	107	3.23	.41	-.10
27 Apr. '54	107	3.22	.40	-.05
14 May '54	109	3.20	.40	-.05
18 June '54	104	3.26	.38	-.10
28 June '54	107	3.23	.44	-.20
26 July '54	103	3.28	.42	-.14
16 Aug. '54	107	3.23	.41	-.14
26 Aug. '54	107	3.22	.42	-.10
1 Sep. '54	102	3.30	.40	-.20
28 Sep. '54	108	3.21	.44	0
4 Oct. '54	99	3.33	.37	-.16
15 Dec. '54	109	3.20	.38	-.13
21 Dec. '54	102	3.30	.35	-.08
25 Jan. '55	120	3.06	.46	-.04

Date	Microns	Md_ϕ	σ_ϕ	α_ϕ
15 Feb. '55	113	3.14	.48	-.04
10 Mar. '55	107	3.22	.43	-.11
22 Mar. '55	112	3.16	.42	-.09
6 Apr. '55	106	3.24	.36	-.36
29 Apr. '55	109	3.20	.40	-.10
5 May '55	130	2.94	.54	0
17 May '55	117	3.09	.45	-.07
8 June '55	113	3.15	.38	-.03
6 July '55	117	3.10	.39	-.30
1 Aug. '55	110	3.19	.34	0
10 Sep. '55	109	3.20	.34	-.12
3 Oct. '55	113	3.15	.36	-.08
12 Oct. '55	102	3.29	.37	-.16
13 Jan. '56	118	3.08	.42	-.10
30 Jan. '56	117	3.10	.36	-.08

APPENDIX IIDD- STATION AT 70-FT. DEPTH

Date	Median Diameter in Microns	Phi Size Distribution Measures*		
		Median Diameter Md_{ϕ}	Deviation Measure σ_{ϕ}	Skewness Measure α_{ϕ}
22 July '53	109	3.20	.38	-.10
19 Nov. '53	109	3.20	.37	-.13
28 Dec. '53	106	3.24	.39	-.08
26 Jan. '54	106	3.24	.38	-.13
27 Jan. '54	109	3.20	.44	-.05
28 Jan. '54	107	3.23	.38	-.08
29 Mar. '54	111	3.17	.42	-.17
27 Apr. '54	117	3.10	.42	-.10
14 May '54	113	3.15	.41	-.02
18 June '54	114	3.13	.38	-.03
26 July '54	109	3.20	.40	-.12
16 Aug. '54	111	3.17	.38	+.03
26 Aug. '54	112	3.16	.42	-.09
1 Sep. '54	110	3.18	.41	-.05
28 Sep. '54	108	3.21	.41	0
4 Oct. '54	111	3.17	.42	-.17
15 Dec. '54	105	3.25	.42	-.07
21 Dec. '54	118	3.08	.40	-.10
25 Jan. '55	121	3.05	.44	-.11
15 Feb. '55	103	3.28	.39	-.13
10 Mar. '55	113	3.15	.42	-.12

Date	Microns	Md_ϕ	σ_ϕ	α_ϕ
22 Mar. '55	110	3.18	.37	-.10
23 Mar. '55	112	3.16	.40	-.02
6 Apr. '55	109	3.20	.36	-.16
20 Apr. '55	110	3.18	.38	-.05
29 Apr. '55	134	2.90	.25	-.20
5 May '55	124	3.01	.42	-.07
16 May '55	117	3.10	.40	-.05
8 June '55	112	3.16	.36	-.06
6 July '55	134	2.90	.32	-.06
1 Aug. '55	129	2.95	.42	-.02
10 Sep. '55	113	3.15	.37	+.03
3 Oct. '55	122	3.03	.42	-.07
12 Oct. '55	119	3.07	.39	-.10
23 Nov. '55	125	3.00	.40	-.05
13 Jan. '56	125	3.00	.45	-.04
30 Jan. '56	122	3.03	.38	-.18

APPENDIX IV
WAVE AND TIDE DATA

APPENDIX IV

Wave and tide data for the beach profile measurements on B range, shown in figure 8.

Date	Survey	Tide* Time	Tide* High (ft)	Tide* Low (ft)	Significant Waves** Breaker Height (ft)	Significant Waves** Period (sec)
22 Sep. '53	High → Low →	0212 0806 1430 2024	5.6 6.1	-0.4 0.1	2.5	7
6 Oct. '53	High → Low →	0206 0754 1424 2012	5.3 4.8	1.0 0.9	1.9 3.0	10 12
8 Oct. '53	High → Low →	0242 0836 1530 2124	5.5 4.2	1.4 0.4	3.1 4.1	10

* Time and height of tide from the U. S. Coast and Geodetic Survey gage on the ocean pier at the Scripps Institution of Oceanography. Datum is MLLW.

** The significant breaker height is the average of the highest one-third of the waves. The number of waves averaged was based on the average period of the groups of highest waves.

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